BASIC PROBLEMS IN THE AIR CONDITIONING
OF STABLES

A paper presented by M.A.R.Kelley,[1] at a symposium on the biological reactions of animals to environmental conditions, at the annual meeting of the American Society of Agricultural Engineers, St. Paul, Minnesota, June 21, 1939.

As I understand it the purpose of this meeting is to increase and make more available our meager store of knowledge about the biological reactions of farm animals under normal conditions. While farmers have always known that adverse environmental conditions affect production, the engineer wishes to have measures of these losses to guide him in design of suitable structures. Over a period of years physiologists have made many tests of the metabolism of farm animals but most of these tests have been with respect to the basal metabolism. I should like to emphasize that in order to design efficient structures for farm animals, engineers need to know more about the heat and moisture production under normal feed and throughout the ordinary range of temperature and humidity conditions.

The present state of development of insulating materials and air conditioning apparatus make possible the maintenance of almost any desired condition. Many people would say offhand that it is impractical to apply these modern inventions to buildings for animals, but we know that practices change and means of reducing the expense of new kinds of equipment are gradually developed.

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Only about twenty five years ago a New England State College published a statement that winter climatic conditions were too severe in its state for profitable raising and handling of dairy cows. Proper insulation was unknown then, but now many successful dairy herds are kept in modern barns in that state.

The agricultural engineer cannot entirely change adverse economic conditions, but he can help immensely in changing a mediocre performance to a successful and profitable farm business. Many large semi-commercial farm enterprises are being developed and ask for technical help. Multi-story poultry houses with capacities from 4,000 to 60,000 birds or more are examples of enterprises where careful design and efficient management may mean the difference between success and bankruptcy.

Scientific design is impossible without data on heat and moisture production under the conditions that can reasonably be maintained, both in winter and in summer. In fact, methods of improving conditions in hot weather are perhaps as urgently needed as methods for providing comfortable conditions during cold weather but the former has had less attention. I have studied the work of various investigators that bear on this subject of summer comfort for farm animals, and should like to present a composite picture that perhaps may have far reaching implications in the solution of this problem.

Tests made in cooperation with the University of Wisconsin and Brookhill Farm (5) from 1930 to 1932 were intended primarily to show the effect of winter environmental conditions upon the milk and butterfat production of milk cows, but it was recognized that the record of the body temperatures, respiration and pulse of the individual cows might produce a more sensitive measure of the environmental conditions than the ordinary thermometer, Babcock tester and milk pail. In this series of tests the cows were fed normal rations and there is every reason to think that during most of the time the cows were comfortable. Therefore, the very complete records of production and physiological conditions that were taken can be used as a sort of bench mark or starting point for comparison with other tests such as those in California (7) and Louisiana (8) which will be referred to later.

A summary of average body temperature, number of respiration per minute and number of pulse beats per minute for all cows in the Brookhill tests is included in table 1 and will be used for comparison with similar data obtained in California under warm conditions.

In this test, with stable temperatures between 46° and 65° F., the herd averages of body temperature of the cows was about 101° F., pulse varied between 61 and 70 per minute and respiration per minute varied from 17.6 at 46° to 29.4 at 64.5°. Naturally there was much more variation in the records of individual cows. For example, during December two of the Brookhill cows, A4 and B2 had body temperatures of 103.8 and 103.2 though they showed no signs of sickness. Under a uniform stable temperature of 60° their rates of respiration and pulse beat were respectively 26.5 and 30.5 breaths and 88.5 and 79.5 pulse beats per minute.

Table 1. Comparison of summer and winter environmental temperatures and their effect on body functions of a dairy cow.

Variable summer environment 1/			Uniform winter environment 2/			
Maximum daily			Average daily			
Temperature		Respiration	Temperature		Respiration	Pulse
Chamber	Body	per minute	Stable	Body	per minute	per minute
Degrees	Degrees		Degrees	Degrees		
			3/			
102	103.2	85	64.5	101.33	29.4	69.5
101	103.5	85	60.0	101.04	26.9	67.3
100	102.8	90	59.7	101.20	28.2	67.8
100	103.5	100	56.7	101.15	21.5	66.3
98	102.9	90	55.6	100.97	23.6	66.8
96	102.8	88	55.2	100.90	22.1	66.0
92	103.0	77	55.2	101.00	22.4	62.9
92	102.2	70	51.3	101.14	19.3	61.2
82	102.6	71	46.0	100.99	17.6	64.1

1/ Data obtained from California, see reference (6) average temperature not available

2/ Data from Brookhill Tests see reference (5) for more complete record

3/ Data for 65° stage was taken from Stable C. All other from cows in stable A.

Studies in the psychrometric room and respiration chamber at the University of California have produced interesting results and reveals certain facts which had previously not been suspected. For example, Regan and Freeborn (7) made studies of the effects of flies and the use of fly sprays on milk production. They found a loss of milk production as high as 21 percent in the presence of an excessive number of stable flies which is of course important. But they also found some new things about the temperature regulation of the cow. I should like first to compare the temperature and rate of respiration of cows under summer conditions with those in the Brookhill tests under winter conditions, as shown in Table 1.

It is of particular interest and significance to note that at a maximum air temperature of 82° in the California tests the respiration rates were more than double those at Brookhill at 65°, and that at air temperatures above 92°, feverish body temperatures resulted and respiration greatly accelerated.

While we have no measure of the depth of breathing or cubic feet of air breathed per minute in those tests, Klieber and Regan (6) do provide information regarding this under warm and cold environmental conditions. Table 2 is a summary of some of their results.

It is noted that under the cold environment of 42° to 48° which is probably below that of the critical temperature of lactating cows (2) that the respiration rate is low and is not definitely affected by the temperature of either hot or cold inspired air and that the depth of

Table 2.--A study of respiration rate and volume of air breathed, when breathing hot and cold air under hot environment also the same comparison for cold environment. (6)

Temperature		Respiration per minute	Depth of breath	Air breathed	
Chamber	Inspired air			per minute	per hour
Degrees	Degrees			Litres	cubic feet
Hot 89.6-98.6	(Hot 87.8-96.8	46.0	2.2	105	222.4
	(Cold 39.2-59.8	28.0	2.7	82	173.7
Cold 42.8-48.2	(Hot 87.8-96.8	15.4	3.6	55	116.5
	(Cold 39.2-59.8	15.4	3.4	52	110.1

breathing is slightly more for the warm air. This suggests that under these conditions the skin temperature controlling the rate of heat loss, makes little demand on respiration to balance the heat production and loss. This is contrasted with the hot environment which calls for two-thirds the rate of respiration when cold air is breathed over that of hot air. It appears that the invigorating effect of the cold inspired air is accompanied by somewhat deeper breath, and that a less volume of air is required to produce the required cooling effect. The Brookhill test afforded added evidence of these reactions. The California tests give results which are indicative of the possible effects and more complete tests are needed that will establish the upper and lower critical points and the optimum conditions.

The reactions of the cows sprayed with oily sprays in this test may have implication of more significance than is generally realized. During the period of high temperatures the oiled cows were in extreme distress, and the sprays appeared to impair the efficiency of their thermo-regulating mechanism. The sprayed cows had an extremely rapid respiration rate of 130 per minute and a body temperature of 105.1.

It was observed in the Brookhill Tests that the skin and the hair of the test cows under a stable temperature of 65° or more, became moist and that the coat was harder to brush and keep clean. In conversation, it has been learned that this has also been observed by others but is not general knowledge.

Therefore, it is of particular interest to find in the California tests that the hourly loss of water at 84° and 60% humidity was 413 grams from the body of the unsprayed cow and 223 grams for the sprayed animal; in other words 31.8 percent of the total heat was lost by evaporation in the first case, as compared to 24.6 percent in the second. Since this water was analyzed and found to contain no appreciable chlorides, it was concluded that the water loss was due to osmosis.

Text books hold that cows do not possess sweat glands, which is doubtless true in the larger sense for the Bos taurus, but as discussed later, is not true for Bos indicus. From this it has been implied that moisture is not lost through the skin. Regulation of body temperature through evaporation of moisture from the skin is of great importance in man and many other animals and these tests imply a similar reaction, but in a narrower range in the case of the cow. Therefore, I have the temerity to raise a question and ask for more information about this form of temperature regulation in the case of the cow, and how her deficiencies in this respect can be overcome. In search for the answer to this question the agricultural engineer is forced to look from the fly spray studies in California to England to study of man, and cross-breeding of livestock in Louisiana and in far off Australia, and then to assemble those thoughts which may lead to a solution of the problem.

The studies of Dr. Whitehouse (9) of England on Sweating and Skin Permeability of man show that water may be lost from the skin in two ways; (a) evaporation from the surface of water which permeates through the skin, (b) evaporation of the trickling sweat secreted by the glands. As the air temperature rises the loss of water through the skin increases rapidly and when at rest with the air of ordinary dryness, practically the whole loss was osmotic until the temperature reached 85° and most of it was osmotic until the temperature was well above body temperature. Other things being equal the osmotic passage of water through the skin varied with the depression of vapor pressure outside the skin and that of the vapor pressure of the blood. At 101° the osmotic loss was 117 grams per hour, representing a heat exchange equivalent to that of the total ordinary resting metabolism of man. It is important to note that notwithstanding the presence of sweat glands the larger part of the water was lost by osmosis through the skin, and that the temperature of 85° is an upper landmark. Thus, these tests on man are in close agreement with those on the cows in California tests. Another interesting phase of Whitehouse experiments concerns the measurement of the transference of CO_2 and O_2 through the skin, starting at 49° F. and increasing rapidly as the temperature rises. Amounts up to about 2 percent of the volume ordinarily given off by the lungs were observed.

The unfavorable effects of high temperature on cows in the California studies are substantiated by other observations. It has been reported that on hot summer days with high humidities that high producing cows may drop in milk production from 7 to 20 pounds in a single day. The prevalence of warm conditions in some localities justify the use of cooling devices to mitigate these losses. The Georgia Agricultural Experiment Station (3) showed that the evaporative cooling principle may be used on cows by applying light blankets sprayed with water. This was found to be effective in maintaining milk yields and no harmful effects are recorded. Also, a large dairy farm in Massachusetts (1) during a hot day last summer found that a ton of dry ice used together with large fans to hasten cooling of 178 cows succeeded in cooling the temperature of stable by 23 degrees and an increase of 84 quarts of milk the next day resulted. Even with high milk prices, this would fall short of a profit but illustrates that comfortable cows do produce more milk.

While engineers can no doubt design structures and equipment to maintain conditions under which cows will give maximum yields, this may not be economically feasible in all sections even if allowance is made for the advances in technical knowledge that we can feel sure will be made. Therefore, I should like to call attention to the work of some animal breeders that may simplify the problem that the engineer is called upon to solve.

In Rhoad's tests the effect of atmospheric temperatures and humidity, solar radiation and shade, on the respiratory rate, body temperature and grazing habits also were observed. Obviously, our time does not permit much discussion of this test, but it is important to note that, when exposed to direct solar radiation under summer climatic conditions, the respiration rate and body temperatures of Bos taurus cattle tend upward toward a febrile condition when exposed for a considerable length of time. This febrile condition was not produced by Brahman cattle of the Bos indicus species which appear to have a more efficient means of disposal and resistance to excess body heat. This faculty, it is shown, may be transmitted by crossbreeding with the Bos taurus species.

Comparing the two breeds on a hot summer day of 88°, the body temperature was 104°+ with a respiration of 125 for the Angus, as contrasted with 101° and 24 for the Brahman. Although the Angus cattle appeared comfortable at morning temperatures of 55° to 58°, Brahman cattle were visibly uncomfortable, showing ruffled coat and some shivering, whereas with the Brookhill cows this condition did not become apparent until a temperature of 46° was reached. Clipping the Angus cows appeared to add to their discomfort when subjected to the direct rays of the sun.

Kelley (4) of Australia provides us with evidence that Bos Indicus, the Brahman cattle of India, do have sweat glands and suggests that our familiar Bos taurus may have possessed these at one stage of their evolution but having developed in the cooler climates their sweat glands have atrophied and are now difficult to find, whereas the Brahman cattle developed in the warmer climate possess sweat glands and the number per square inch may be counted by aid of a suitable microscope.

Rhoad (8) of Louisiana found that by crossing Aberdeen Angus cattle with the Zebu or Brahman cattle of India that the pyrexial point, and ability to withstand heat was raised from that of the Angus purebred, by the quarter-bred and half bred toward the higher resistance of the pure bred Brahman. In this case there is a mixing of two breeds, one from Bos taurus species and the other Bos indicus. This suggests possible future development and improvement of cattle for southern conditions.

A notable example of this possibility was witnessed a few years ago on the famous King Ranch of Texas. Here the Shorthorn and the Brahman have been crossed and a new breed, the Santa Gertrudus, developed, a living model produced by a master breeder which the artist and sculptor may envy. These experiments reveal a possible change in the natural cooling of cattle and their ability to resist heat.

In closing, the engineer needs to have further knowledge of the effects of normal environmental conditions on farm animals. For such information we are dependent upon calorimeter tests under controlled conditions in order that the variable factors may be reduced to a minimum. We are grateful to our friends who deal more directly with animals for the papers which have been presented here today. These should be very helpful to the agricultural engineer in his design of more efficient and comfortable quarters for livestock. We hope that future investigations will further add to the basic knowledge of this subject.

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